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Separate vertical wiring for the fixation of comminuted fractures of the inferior pole of the patella

K. H. Yang, Y. S. Byun

From Youngdong Severance Hospital, Seoul, and Daegu Fatima Hospital, Daegu, Korea

Comminuted and displaced fractures of the inferior pole of the patella are not easy to reduce and it is difficult to fix the fragments soundly enough to allow early movement of the knee. We have evaluated the clinical effectiveness of the separate vertical wiring technique in acute comminuted fractures of the inferior pole of the patella. A biomechanical study was also performed using ten pairs of embalmed cadaver knees. A four-part fracture was made on the inferior pole of the patella and fixed by two separate vertical wires on one side and two pull-out sutures after partial patellectomy on the other.

The ultimate load to failure in the first group was significantly higher than in the second (250.1± 109.7 N *v* 69.7 ± 18.9 N, p<0.002), as was the stiffness (279.9 ± 76.4 N/mm *v* 23.2 ± 11.4 N/mm, p<0.001).

The separate wire technique was used in 25 patients with comminuted fractures of the inferior pole of the patella who were followed up for a mean period of 22 months (10 to 50). All the fractures healed at a mean of seven weeks (6 to 10). No breakage of a wire or infection occurred. The mean grading at the final follow-up was 29.5 points (27 to 30) using the Böstman method. This technique preserved the length of the patella, fixed the comminuted fragments of the inferior pole and avoided long-term immobilisation of the knee.

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Displaced fractures of the patella which disrupt the extensor mechanism of the knee require operative treatment. Fixation by lag screw or tension bands has been advocated except for fractures which are severely comminuted and need partial or total patellectomy. The inferior pole is the site of 5% of fractures of the patella and can be treated by tension-band wiring, circumferential wiring or with screws if the fragment is sufficiently large.[1-4] Such fractures, however, are often comminuted and difficult to manage. Excision of the small fragments of bone with attachment of the patellar tendon by transosseous pull-out suture is usually indicated. Weakness of synthetic non-absorbable sutures and partial patellectomy require immobilisation of the knee after operation, which delays rehabilitation and may result in weakness of the quadriceps muscle. Some authors advocate patellotibial cerclage or the use of figure-of-eight wiring to protect the pull-out suture in order to allow early rehabilitation, but these procedures make it difficult to adjust the length of the patellar tendon. This may result in breakage of the wire requiring a second operation for its removal.[3-6]

After a biomechanical study we have evaluated the clinical effectiveness of the separate vertical wiring technique in acute comminuted fractures of the inferior pole of the patella.

Material and Methods

Biomechanical study. We used ten pairs of embalmed cadaver knees with a mean age of 74.2 years (40 to 93) to model acute comminuted fractures of the inferior pole of the patella. The patella, patellar tendon and the tibial tuberosity were isolated and removed. The soft tissue and bony spur were removed from the articular side of the patella and its tendon in order to expose the inferior pole. The length of the patella was then measured. An initial transverse osteotomy was made at the inferior margin of the articular surface of the patella using a micro-oscillating saw starting from the articular side and perpendicular to the bone. A coronal osteotomy of the inferior pole was made along the long axis towards the tip and a sagittal osteotomy performed from the centre of each fragment. The four fragments mimicked a four-part comminuted fracture of the inferior pole. In one of the pair of knees the fragments were fixed by two separate vertical wires. In the other they were excised and the patella and its tendon approximated by two transosseous pull-out sutures. Separate vertical wiring was performed on the right

K. H. Yang, MD, Professor
Department of Orthopaedic Surgery, Youngdong Severance Hospital, 146-92, Dokokdong, Kangnamku, Seoul, Korea.

Y. S. Byun, MD, Chairman
Department of Orthopaedic Surgery, Daegu Fatima Hospital, 302-1, Shinamdong dongku, Daegu, Korea.

Correspondence should be sent to Professor K. H. Yang.

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Table I. Details of the patients. The results are based on the grading scale of Böstman et al[7]† at the latest follow-up

Case	Age (yrs)	Gender	Operation time (mins)	Number of wires	Time to union (days)	Follow-up (mths)	Complications	Results	Removal of wire
1	30	F	65*	2	45	24		30	
2	25	M	120	3	44	12		30	0
3	54	M	90	3	72	12		30	0
4	17	M	90	3	42	44		30	0
5	25	F	60	3	54	31		28	0
6	18	F	60	3	42	28		30	
7	46	M	60	3	40	48		30	0
8	56	M	135	3	40	50		28	
9	57	F	100	4	53	41	Re-operation after a fall	30	
10	24	M	80	4	42	13		30	
11	24	M	75	3	46	50		30	
12	20	M	90	2	45	41		30	
13	67	F	75	3	40	12		30	
14	52	M	85	3	68	12		28	
15	24	M	90	3	56	12		30	
16	40	M	90	4	56	12		30	
17	25	M	70	3	56	14		30	
18	60	F	80	3	52	30	Loosening	30	
19	47	M	75*	3	67	26		29	
20	24	M	80	3	42	13		30	
21	46	M	90	3	47	13		27	0
22	36	M	75	4	50	12		30	
23	29	M	75	3	42	12		28	
24	28	M	80	4	56	12		30	
25	46	M	60	3	42	10		29	

*combined fixation with a screw or a modified tension-band wiring
†see Table II

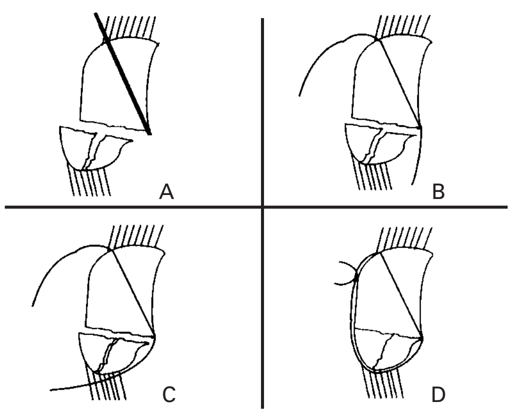

Fig. 1

The separate vertical wiring technique. The anterior and posterior fragments are drawn closer during tightening of the wire.

side when the registered case number was odd. The length of the patella was measured after each procedure.

Methods of fixation.

Separate vertical wiring (SVW) technique. A number one Steinmann pin with a small hole at its end was inserted vertically from the anterosuperior aspect of the patella to the most posterior aspect of the transverse osteotomy. A medial bone tunnel was made to fix the anterior and posterior fragments on the medial side of the inferior pole and a lateral tunnel was made for the two lateral fragments. A wire suture of 0.75 mm diameter was passed through the hole in the Steinmann pin when its tip emerged from the site of the osteotomy. The Steinmann pin was then withdrawn with the wire. The proximal end of the wire was held using a Kelly clamp and the distal end passed through the patellar tendon as close as possible to the bone from the posterior aspect of the two bone fragments. The distal end of the wire was then pulled anteriorly, twisted and tightened with the proximal end at the anterosuperior aspect of the patella (Fig. 1).

Transosseous pull-out suture of the patella tendon (POS). The fragments of bone were excised from the proximal part of the patella tendon. The Bunnel suture technique, using two number one nylon sutures, was used on the medial and lateral halves of the tendon. Four parallel bony tunnels were then made as described above, and the free proximal ends of the sutures were passed through the bony tunnel using a suture passer. Two lateral bony tunnels were used to attach the lateral half of the patellar tendon, and two medial tunnels to attach the medial half. The sutures were tightened securely.

Mechanical testing. The patella, patellar tendon and the tibial tuberosity were mounted and loaded with uniaxial tension on an Instron machine (model 6022; Instron Co, Canton, Massachusetts). The patella and tibial tuberosity were fixed to the proximal and distal clamp respectively using two number three Kirschner wires. The speed of loading

Fig. 2a

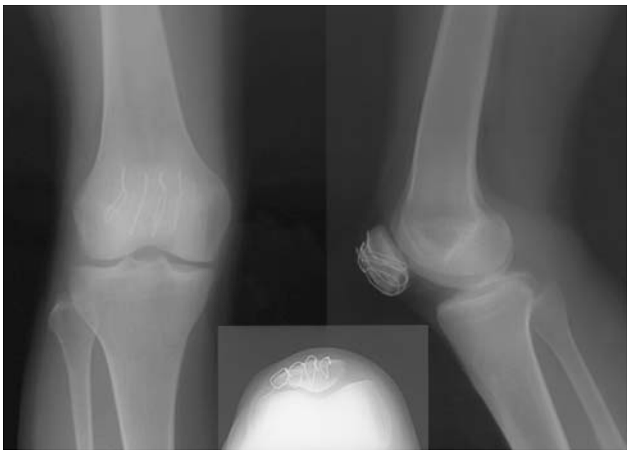

Fig. 2b

Figure 2a – Lateral radiograph showing displaced and comminuted fractures of the inferior pole. Figure 2b – Anteroposterior, lateral and skyline radiographs showing four comminuted fragments reduced and fixed by four separate vertical wires.

Table II. Details of the clinical grading scale of Böstman et al[7]

Variable	Point
Range of movement (ROM)	
Full extension and the ROM >120° or within 10° of the normal side	6
Full extension, movement 90° to 120°	3
Pain	
None or minimal on exertion	6
Moderate on exertion	3
In daily activity	0
Work	
Original job	4
Different job	2
Cannot work	0
Atrophy, difference of circumference of thigh 10 cm proximal to the patella	
<12 mm	4
12 to 25 mm	2
>25mm	0
Assistance in walking	
None	4
Cane part of the time	2
Cane all the time	0
Effusion	
None	2
Reported to be present	1
Present	0
Giving way	
None	2
Sometimes	1
In daily life	0
Stair-climbing	
Normal	2
Disturbing	1
Disabling	0
Total score	
Excellent	30 to 28
Good	27 to 20
Unsatisfactory	<20

was 1mm/minute, and the ultimate load-to-failure and stiffness of each specimen were recorded. The test was stopped when the bone failed or the transverse osteotomy gap exceeded 3 mm.

Statistical analysis. This was performed using the Wilcoxon signed-rank test. The level of significance was set at $p<0.05$.

Clinical study

Between March 1996 and May 2001 we treated 29 consecutive patients with a comminuted fracture of the inferior pole of the patella. Two were excluded because of an associated partial avulsion of the patellar tendon which required a protective patellotibial cerclage wire, and two were lost to follow-up. Twenty-five patients were treated as described above and followed up for a mean period of 22 months (10 to 50) (Table I). Their mean age was 37 years (17 to 67). A longitudinal or a transverse incision was used depending on the damage to the prepatellar skin. The site and the number of vertical wires depended on the location and the number of fragments of the inferior pole (Fig. 2). Each wire encircled the main fragments of the inferior pole. The soft tissue around the site of the fracture was sutured with 1-0 Vicryl to stabilise the small fragments. After the operation the knee was immobilised in a long-leg splint for two days after which continuous passive movement and quadriceps exercises were started. The knee was protected with a brace which limited flexion to 60° during passive exercise for one month. The brace was locked in extension during rest and when walking with crutches for one month. Flexion of the knee was increased to 90° in the second month. Radiological union was defined as the obliteration of all fracture lines between the body and the inferior pole in the anteroposterior and lateral views. When there were small separated peripheral fragments, the main fragments were assessed when deciding union. The function of the knee was evaluated using the method of Böstman, Kiviluoto and Nirhamo[7]

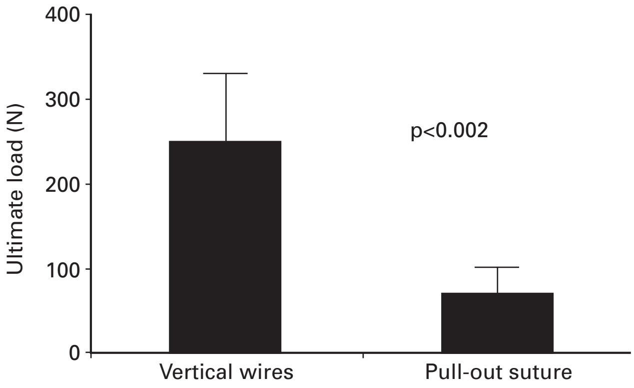

Fig. 3

The ultimate load to failure in separate vertical wiring and pull-out suture after partial patellectomy. The vertical bars indicate one SD.

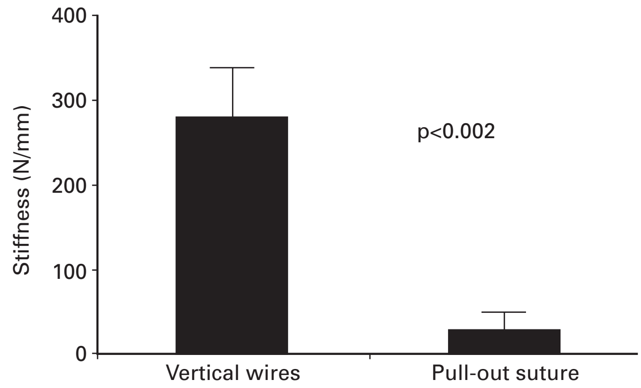

Fig. 4

Stiffness in separate vertical wiring and pull-out suture after partial patellectomy. The vertical bars indicate one SD.

by one of the authors (YSB) at the latest follow-up (Table II). This study was performed prospectively to evaluate the time to union and retrospectively to assess the functional results.

Results

Biomechanical study. The lengths of the patella before osteotomy were 5.98 ± 0.32 cm in the separate vertical wire group and 5.99 ± 0.32 cm in those managed by pull-out sutures. After osteotomy and fixation, the lengths were 5.63 ± 0.34 cm and 5.24 ± 0.27 cm, respectively.

The ultimate load to failure in the wired group was significantly higher than in that with pull-out sutures (250.1 ± 109.7 N *v* 69.7 ± 18.9 N, $p < 0.002$, Fig. 3). In the former group all failure occurred at the site of the bone fragments. Measurements were stopped when the tendon-bone junction was separated by 3 mm in the sutured specimens. Stiffness in the wired specimens was significantly higher than in those which had been sutured (279.9 ± 76.4 N/mm *v* 23.2 ± 11.4 N/mm, $p < 0.002$, Fig. 4).

Clinical study. The mean length of operation was 79 minutes (60 to 135). Three separate vertical wires were used in most cases. In five patients there was an associated fracture of the body of the patella. Two were vertical fractures which were fixed by an additional screw or by using modified tension-band wiring. Three were transverse fractures of the body that were fixed using a modified, separate, vertical wiring technique in which the middle fragment was temporarily fixed to the remaining superior segment using two Kirschner wires. Separate vertical wiring was then used to stabilise the body fragments and the inferior pole. The Kirschner wires were then removed when the fixation was firm. Radiographs of the knee were taken every two weeks until union was established and then every two months until six months after operation.

The fractures healed at a mean of seven weeks (6 to 10). Delayed union of the small separated fragments from the inferior pole was seen in two patients, taking six months until union to the inferior pole. This did not limit the function of the knee after the union of the main fragments.

One woman aged 57 years fell one week after operation and disrupted the fragments. We repeated the procedure using more wires and obtained union at eight weeks. Slight separation at the site of the fracture was seen in a 60-year-old woman two weeks after operation. Her knee was immobilised in a cylinder cast for six weeks; the fracture united at eight weeks. Fractures occurred in two patients with pre-existing degenerative osteoarthritis of the patellofemoral joint. We saw no evidence of post-traumatic arthritis or progression of pre-existing osteoarthritis of the patellofemoral joint at the latest follow-up. Breakage of wires or infection was not seen. The mean grading at the final follow-up was 29.5 points (27 to 30) by the method of Böstman et al.[7]

Discussion

Comminuted and displaced fractures of the inferior pole of the patella are difficult to reduce and fix firmly enough to allow early movement of the knee. The inherent weakness of the bone and the size of the fragments prevent firm stabilisation by ordinary wiring or screws. Augmentation with patellotibial cerclage or figure-of-eight wire often results in multiple segmentation of the wire (Fig. 5),[1,3,5] and may cause discomfort at the anterior aspect of the knee because of tenting of the wire loop during flexion and extension. Tightening of the cerclage wire often decreases the length of the patellar tendon and may injure the soft tissue in front of the tendon and the tibial tuberosity causing scarring and subsequent patellar baja. A low-lying patella disrupts the normal physiology of the patellofemoral joint.[2] Our new technique allows restoration of the length of the patella and minimal injury to the tendon.

The intraosseous bone wire suture was first introduced by Lister.[8] He constructed oblique bone tunnels in each fragment of a mid-patellar fracture and fixed them by wire

Fig. 5a

Fig. 5b

Radiographs showing comminuted and displaced fractures of the inferior pole internally fixed using the modified tension-band method, augmented by a circumferential wire and a patellotibial cerclage wire. Multiple segmentation of the wires and patella baja are shown.

loops. Our technique is a modification of his method. We encircle the fragments of the inferior pole of the patella with separate vertically orientated wires, because the fragments are too small to make bone tunnels. The number of wires used is dictated by the number and location of the fragments. The method allows the anterior and posterior fragments to be aligned by tightening the wires as shown in Figure 1.

The direction of the forces applied to the patella changes during flexion and extension.[1,3,9-11] In extension the patella is subject to two opposing linearly arranged forces along the line of the quadriceps and patella, but in flexion there are posterior forces along the superior and inferior poles and an opposing anterior force when the posterior surface of the patella comes in contact with the femur. A tension force is applied on the anterior surface of the mid-patella and a compressive loading force on the articular surface. It is thus necessary to test the technique of fixation for fractures of the middle portion of the patella in various positions. Because the inferior pole of the patella lies outside the patellofemoral joint we performed a distraction test on the patella-patellar tendon-tibial tuberosity complex. Regardless of the position of the knee, the wires which encircled the inferior pole were found to counteract the tensile force and to keep the fragments in the reduced position. Excessive tensile forces always resulted in failure of the bony fragments. Although the ultimate load causing failure was about half of that found for the modified tension-band wiring technique in fractures of the mid-patella,[9,10] it appears to be the maximum force which can be sustained by the inherently weak fragments. The even load on the quadriceps tendon required to achieve full extension of the knee in the biomechanical study was 316 N.[11] Higher loads are generated during exercises. The mean ultimate load before failure in our study was 250 N after separate vertical wiring. Hence, sudden uncontrollable contraction of the quadriceps muscle may cause failure of the fixation as occurred in one of our patients.

Our study is limited by the lack of a control group in the clinical arm. Since partial patellectomy is a final option in the treatment of comminuted fractures of the inferior pole of the patella, we performed open reduction and internal fixation to attempt to retain the inferior pole in every case. Union of the extra-articular fracture may maintain the length of the patella and decrease the risk of patella baja, without increasing the risk of post-traumatic arthritis. Severe comminution of the body of the patella may require partial patellectomy and re-attachment of the inferior pole of the patella or patellar tendon to the proximal fragment.

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